Code R Base Technology Program

Pioneering Revolutionary Technology Overview

Presented to the Earth Science Enterprise

Technology Strategy Planning Team

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Aerospace Technology

Strategic Program Area

- Revolutionize Aviation (Blueprint)
- Advance Space Transportation (ISTP)
- Pioneer Revolutionary Technology
- Commercialize Technology

Objectives (Theme Areas)

Revolutionize Aviation: Safety, Noise, Emissions, Mobility, Capacity

Advance Space Transportation: Safe, Affordable, Mission Reach

Pioneer Revolutionary Technology: Ultra Efficiency, Self-Reliance, Science Measurement & Detection, Design for Safety

Commercialize Technology: Technology Development Partnerships

Programs

Revolutionize Aviation: Safety, Vehicle Systems, Airspace Systems

Advance Space Transportation: 2nd Gen RLV, Space Transfer & Launch Technology

Pioneer Revolutionary Technology: Enabling Concepts and Technologies (ECT), Computing, Information and Communications Technology (CICT), Engineering for Complex Systems (ECS)

Commercialize Technology: Commercial Technology Program

FY 00/01 to FY 03 Budget Re-Map

CETDP and Aerospace Base Elements	PRT Strategic Program Group ($276M in FY 03)
Breakthrough Sensors & Instruments Distributed Spacecraft Micro/Nano Sciencecraft Ultra-lightweight Structures Advanced Power & On-board Propulsion Space Environmental Effects Advanced Energy Systems	Enabling Concepts and Technology (ECT), $93M*
Thinking Space Systems Atmospheric Systems & In-Space Ops Surface Systems High Rate Data Delivery ~~HPCC~~ IT Base Bio-nano-technology (computing, electr., mat'ls, sensing)	Computing, Information & Communication Technology (CICT), $155M
~~Next Generation Infrastructure~~ ~~ISE~~	Engineering of Complex Systems (ECS), $28M

* Enabling Concepts and Technologies includes the Cross Enterprise NRAs ($40M)

FY 2002 Continuation of CETDP 3-Year Tasks Begun in FY 2000, $52.3M

ECT, Tasks $37.5M

- Breakthrough Sensors and Instrument Components ($18.5M) – JPL 31 tasks, $15.9M; GSFC, 7 tasks, $1.5; LaRC, 4 tasks, $1.1M
- Distributed Spacecraft ($1.6M) - JPL 3 tasks, $1M; GSFC 3 tasks, $0.6M
- Micro-Nano Sciencecraft ($2.7M) – JPL, 9 tasks $1.9M; GSFC, 3 tasks, $0.8M
- Ultralightweight Structures and Observatories ($2.2M) – JPL, 5 tasks $1M; LaRC, 4 tasks, $1M; GSFC, 1 task, $0.2M
- Adv. Power and Electric Propulsion ($12.5M) – GRC, 22 tasks, $12.3M; GSFC 1 task, $0.2M

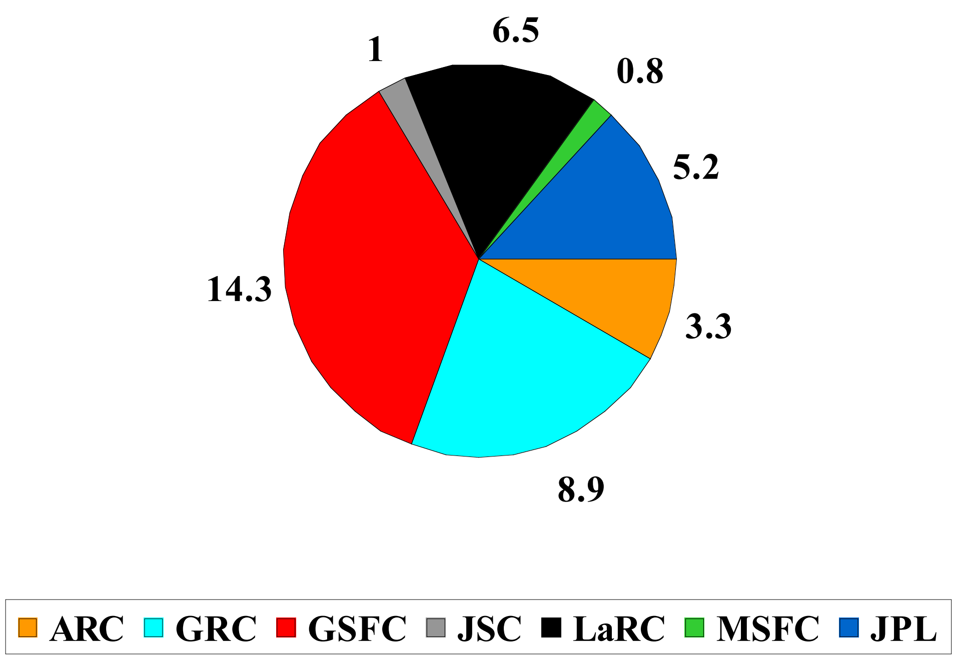
CICT, Tasks $14.8M

- Thinking Systems ($10M) – JPL, 7 tasks, $1.1M: ARC, 20 tasks, $8.4M ; GSFC, 3 tasks, $0.5M
- High-Data-Rate Delivery ($3.5M) – JPL, 8 tasks, $1.5M; GRC, 6 tasks, $2M; Atmospheric Systems and In-Space Operations – JPL, 1 task, $0.25M
- Surface Systems ($1.3M) – JPL, 5 tasks, $1.3M

CETDP NRA – $40M in FY 2002

$120M Total FY 2001-FY 2003

Distribution by Center, $M



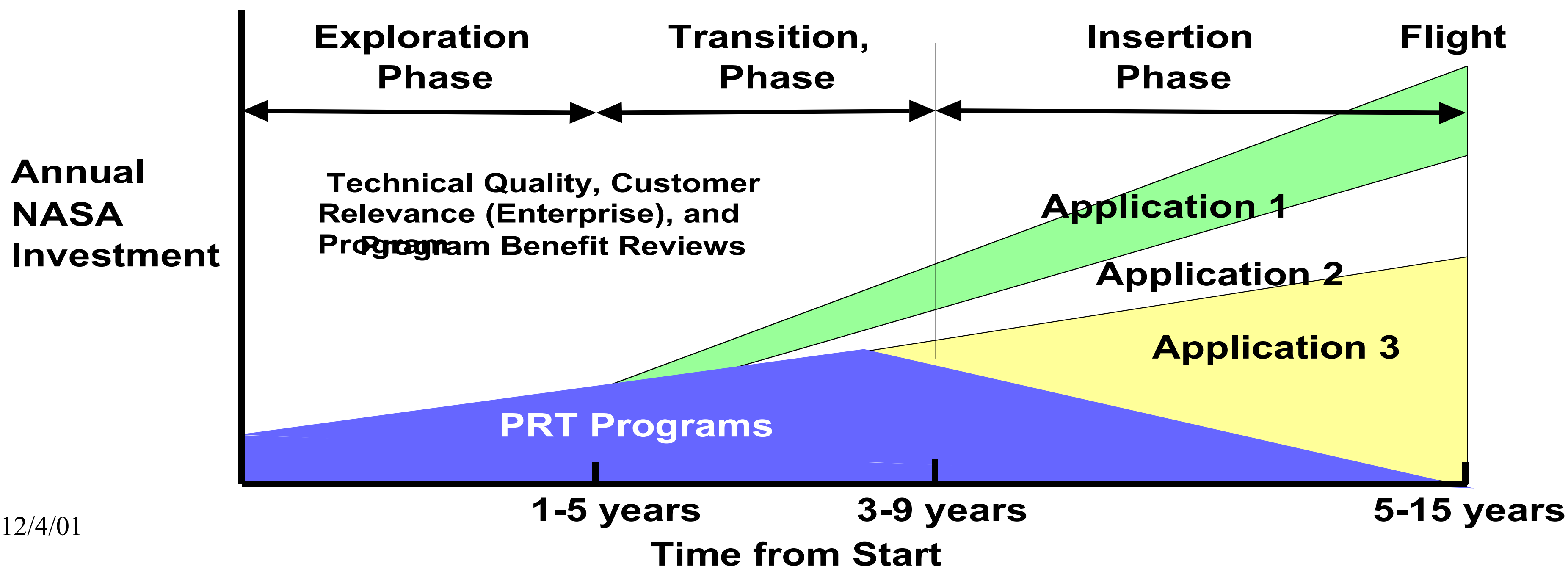
Code Y Ratings of 112 Winning Proposals

Code Y Relevance Score	Number of Proposals	Total Value FY 01- FY 03
Excellent (91-100)	28	$28.0M
Very Good (81-90)	10	$12.6M
Good (71-80)	12	$15.6M
Totals	50	$56.2M

Approximately $6M in other NRA's are in ECT FY 2002 Program

Technology Investment Phasing

- ECT will follow through on technologies transition and insertion
  - Phase I – Exploration: ideas, systems, and concepts
  - Phase II – Transition: growing ***user investment required***
  - Phase III – Insertion: investment to assure measurement and evaluation
- Failure to progress through phases leads review for possible termination and rollover into new exploration phase
- ***Cost will reduce number of things that can be researched***

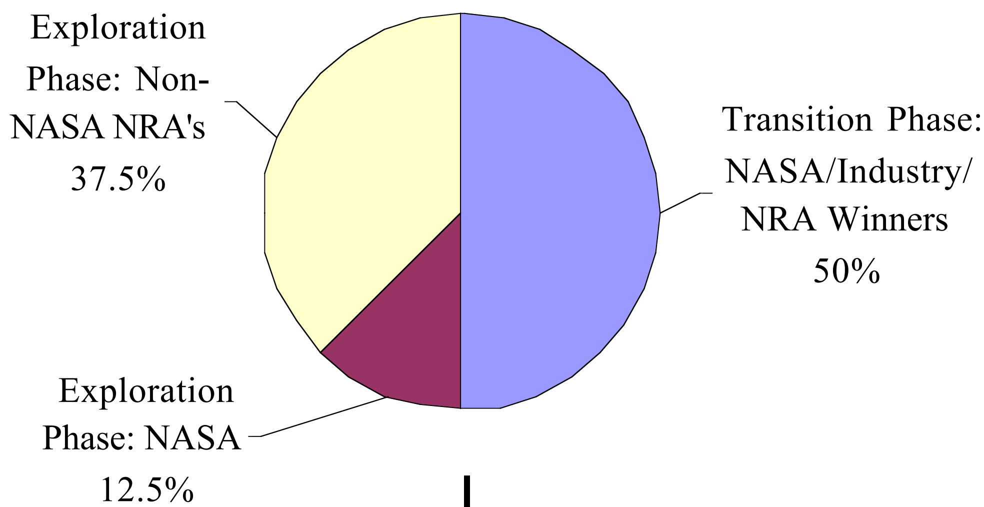


Funding Allocation Strategy

Exploration Phase
TRL 1-3, 50 Percent

Transition Phase
TRL 4-9, 50 Percent (Goal)

75 percent of Exploration Phase by NRA



100 percent of Transition Phase by Partnerships

- NASA Centers will not compete in Exploration Phase NRA's
- New NASA Exploration-Phase activities coordinated with advisory committees

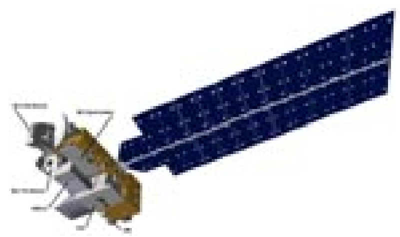
- Transition Phase requires customer co-funding by bid and/or negotiation
- Successful Exploration Phase NRA partners participation varies, estimated 12.5 to 37.5 percent estimated depending on role

ECT Major Program Products

Advanced System Concepts ($12M)

FY 02 Mission Study Example: Earth Science

- **Study of Revolutionary Earth Sciences Architecture for Atmospheric Chemistry, Earth Radiation Balance, and Geomagnetism Measurements**
  - Dr. Shahid Habib, GSFC
  - A range of advanced platforms required for making Earth science measurements in the upper stratosphere will be investigated
  - The revolutionary technologies necessary for each platform needed to make the desired measurements will be identified



Subsystems Analyses (Preliminary)

Onboard-power and electric propulsion examples:

- SBIRS
- TRMM

Space Communications and Data Delivery – generic definition studies:

- Space network architectures
- Earth science systems

Avionics:

- Ultra-low power for EO-1

Instrument Components:

- General methodology and examples needed for integrated evaluation of components pay-off in systems

Bottom Line – Need to establish "what if" full **<u>system</u>** life-cycle assessment capability and baselines for space missions

Enabling Concepts and Technology (ECT) Program - $92.9M* in FY 03

* Includes broadly distributed $40M Cross-Enterprise NRA)

Advanced System Concepts Project ($12M) - Conceptual studies and systems analysis of revolutionary aerospace system concepts

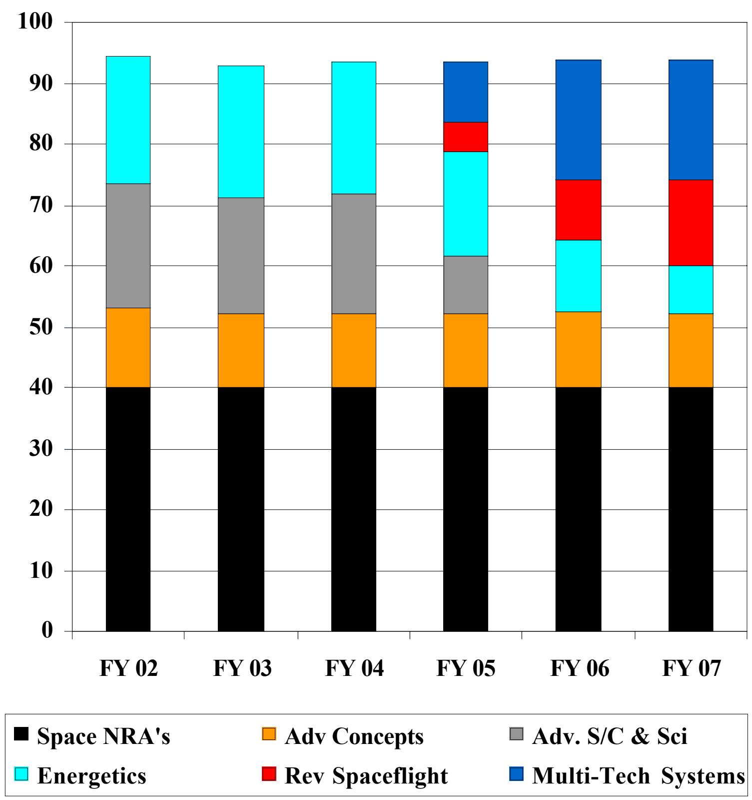
Energetics Project ($21.6M) - Advanced power and propulsion technologies

Advanced Spacecraft and Science Components Project ($19.3M) - Advanced sensing and spacecraft systems technologies

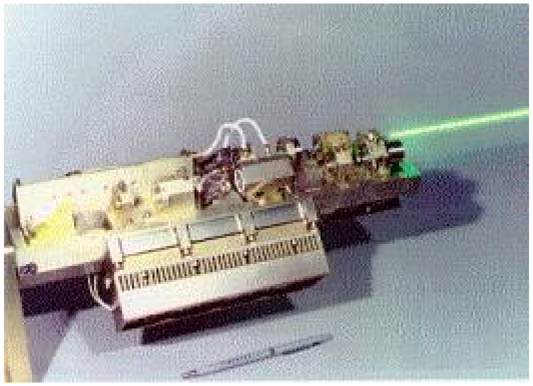
Multi-Technology Integrated Systems Project (future) - Technology products from multiple projects integrated into proof-of-concept systems

Revolutionary Space Flight (future) - Integrated Revolutionary Power and Propulsion Systems

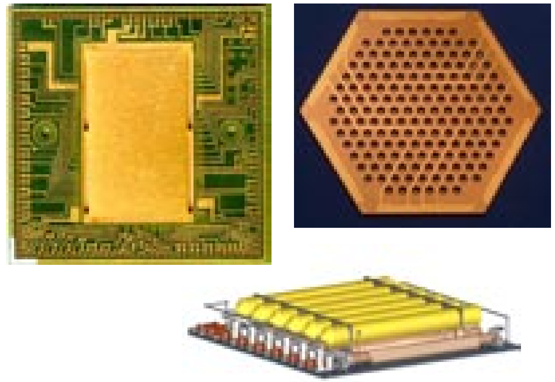
ECT Funding, $M



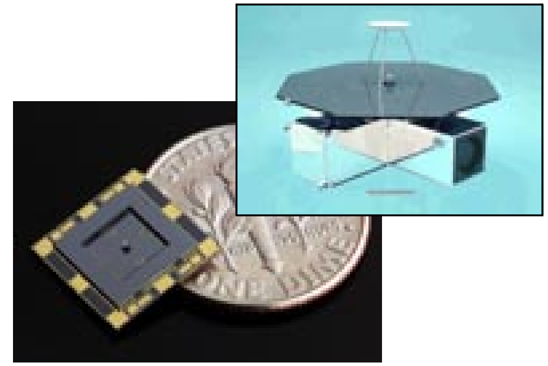
ECT Major Program Products
Advanced Spacecraft & Science Systems ($19.3M)



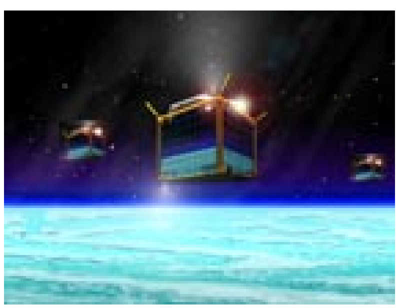
High efficiency, low mass, tunable laser transmitters



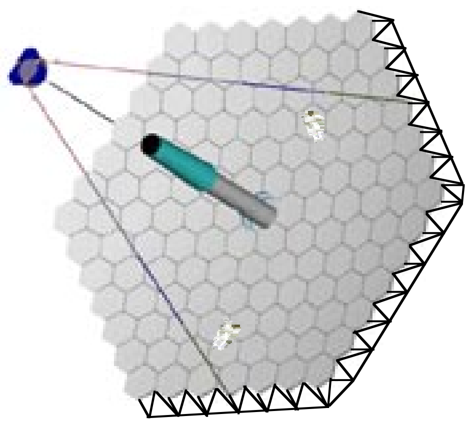
High efficiency detectors and cryo-coolers for focal plane assemblies



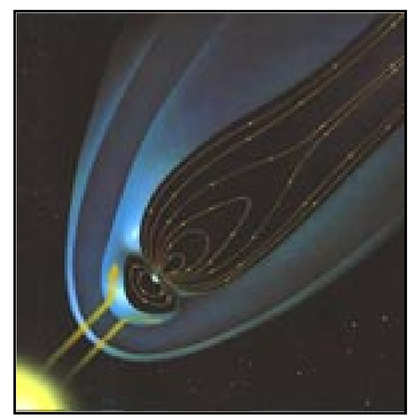
Micro-avionics and multifunctional structures to reduce spacecraft mass and launch volume by 3x



Relative position sensors and control algorithms for distributed spacecraft systems



Concepts for enabling 50+ meter class structures and apertures



Space environment models and analytical tools for predicting environmental effects on spacecraft systems

FY02 Joint Laser Technology Program

LaRC

Laser Risk Reduction Program (LRRP), Code-Y
Estimated $ 2.0M

- 2-Micron Laser Transmitter
- Laser Diodes
- Wavelength Conversion

Enabling Concepts and Technology Program (ECTP), Code-R
$ 2.1M

2-Micron Laser Transmitter

- Breadboard CO2 DIAL
- Breadboard WIND Transmitter
- 2-um Detector Development
- Receiver Subsystem
- Multi-Use Lidar Transmitter 3-9 um

Quantum Mechanical Modeling and Advanced Materials

Wavelength Conversion

NRA Awards
Code-R $ 0.9M
Code-Y $ 0.6M

2-Micron Laser Transmitter

Code-Y ATIP

- Laser Diode for DIAL
- High Power Laser
- Multi-Use Lidar Transmitter, 3-9 um

Code-R CETDP

Water Vapor DIAL

Code-Y ATIP

GSFC

LRRP, Code-Y
$ 2.0M

- 1-Micron Laser Transmitter
- Laser Diodes (808nm)
- Injection Seeding for Wavelength Control

ECTP, Code-R
$1M

1-Micron Laser Testbed

- Laser Architecture/System/Components
- Opto-mechanical design
- Contamination
- Damage Tolerance
- Heat Removal
- Environmental testing

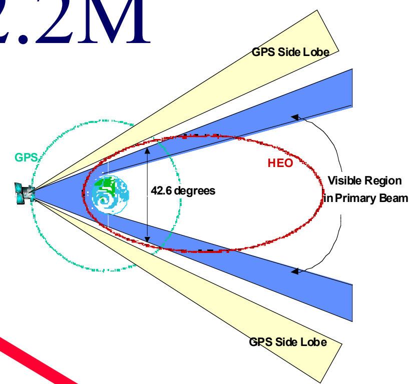
NRA Awards, Code-R
$ 0.3M

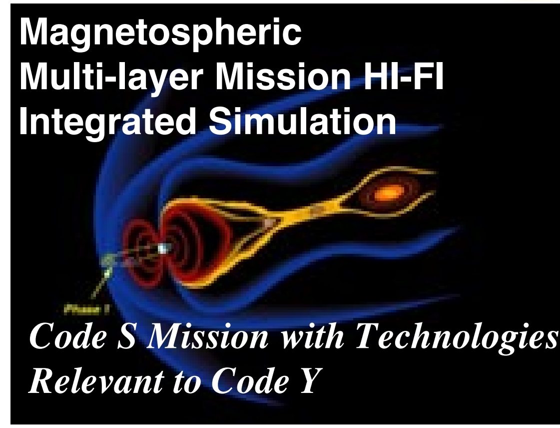
Semiconductor Laser Source

Code-R CETDP

Task Synergy

Distributed Spacecraft Systems Technologies - $2.2M



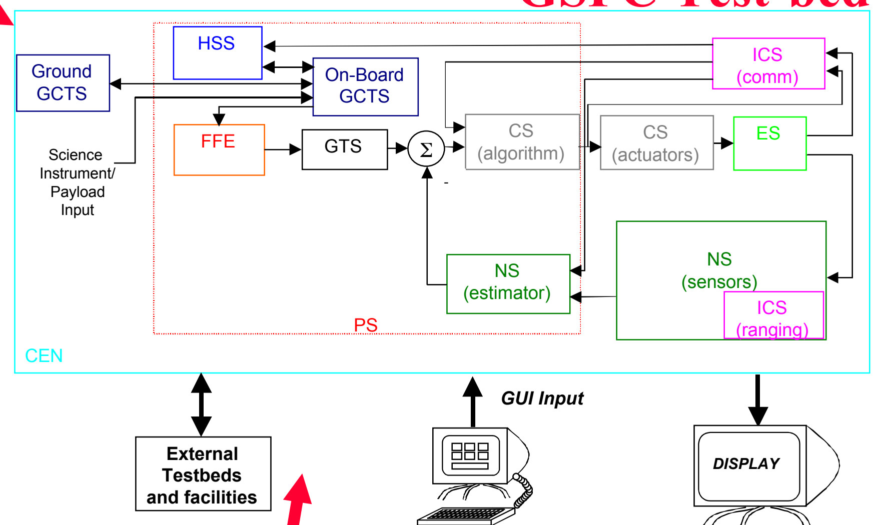


High-Altitude Relative Navigation

Formation Flying

Decentralized Control of Formations

GSFC Test-bed



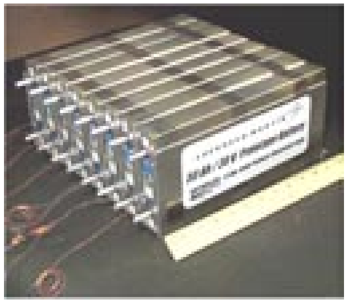
University NanoSats and Intersatellite Community

Developing and integrating technologies into system solutions that enable multi-spacecraft missions

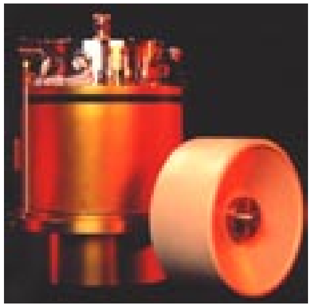
ECT Major Program Products
Energetics - $21.6M

High efficiency space power systems to reduce mass by 50%

Advanced photovoltaics



Batteries & fuel cells



Flywheel energy storage

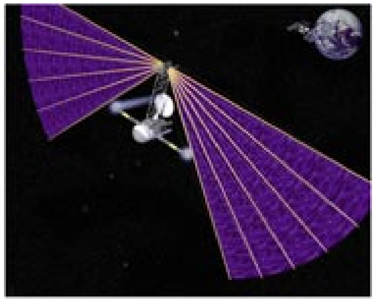
High efficiency on-board propulsion systems to propellant reduce mass by 50%

Pulsed plasma thrusters

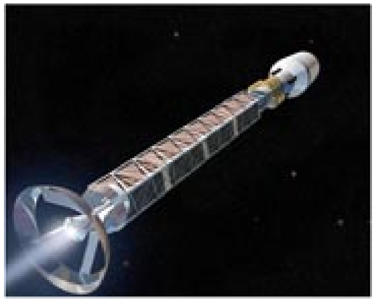
Micro-ion thrusters

Hall thrusters

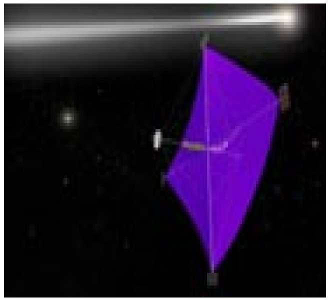
Revolutionary propulsion systems to reduce trip times for interplanetary missions by 30%



Advanced electric propulsion



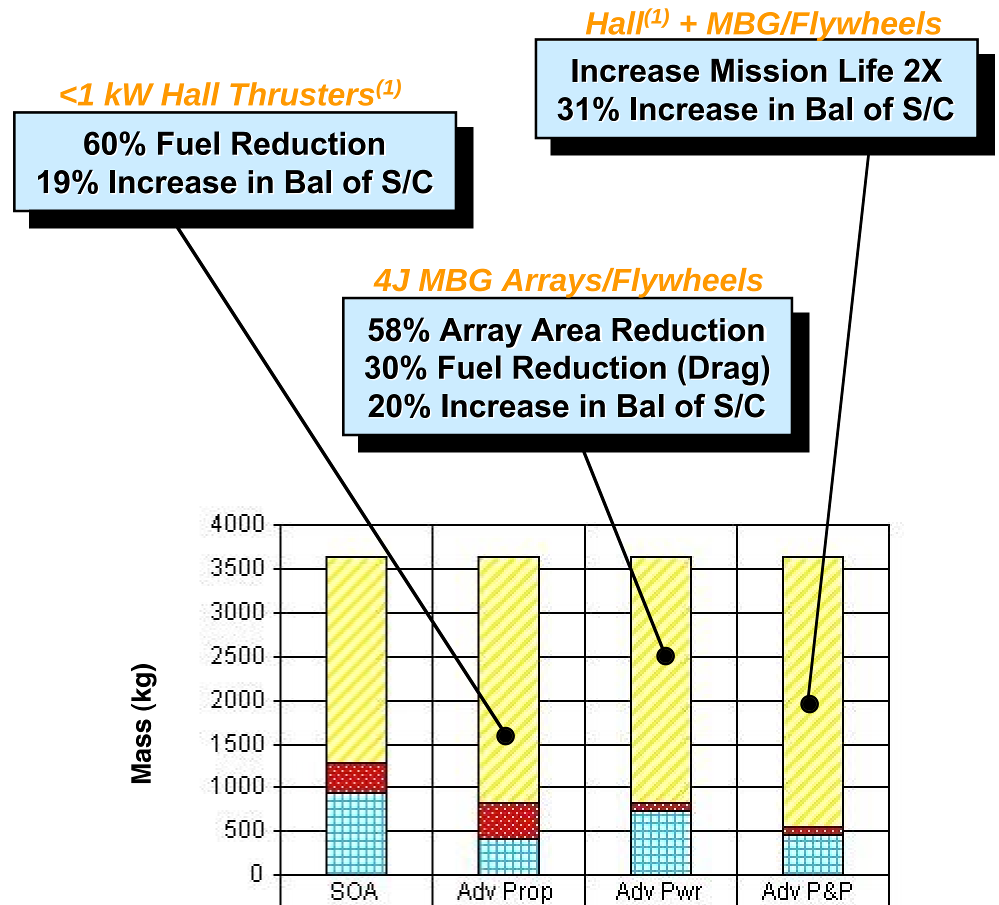
Nuclear fission, nuclear fusion, antimatter propulsion



Solar sails

TRMM

- Launched Nov '97 on H-II (Japan)
  - 350 km Altitude, 35° Inclination
  - 3.5 year Mission Life
- Bus Power 1100 Watts
  - 3.4 kW GaAs Array
  - 670 Whr NiCd Batteries
- Hydrazine Propulsion
  - Orbit Maintenance (650 kg Fuel)
  - Controlled Re-entry (240 kg Fuel)



	SOA	Adv Prop	Adv Pwr	Adv P&P
Bal of S/C	2332	2781	2801	3062
Power	326	435	73	104
Prop	961	404	746	454

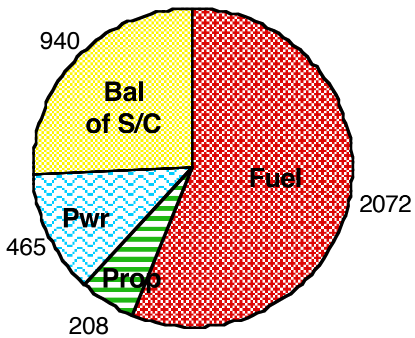
(1) The use of Hall thrusters for orbit maintenance requires coincident use of bus power for payload and propulsion; add'l array added for Hall system

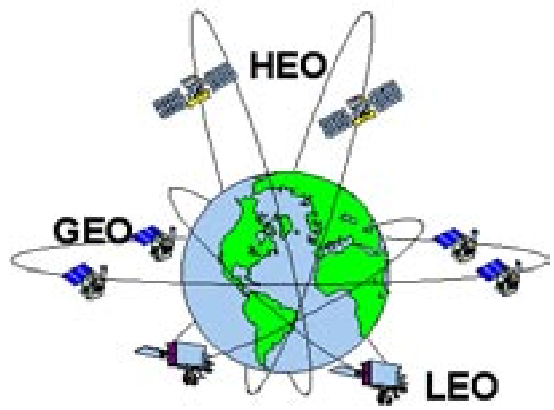
SBIRS High (GEO)

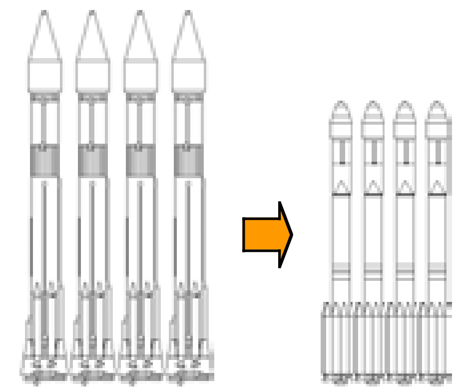
GaAs/NiH2
NTO/MMH Insertion,
SK, Repos.

3685 kg Launch Mass
6.5 kW Array (BOL)
10 Year Spacecraft Life
10x14 Day 90° Repositions

State-of-the-Art
Atlas IIAS



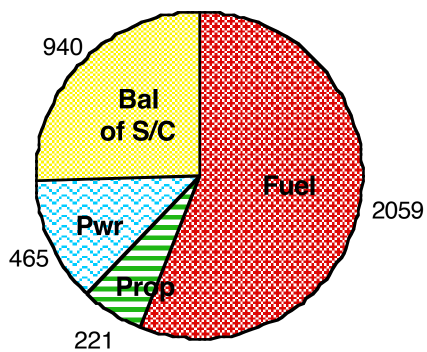




GaAs/NiH2
NTO/MMH Insertion
5 kW Hall SK, Repos.

3685 kg Launch Mass
6.5 kW Array (BOL)
15 Year Spacecraft Life
45x9 Day 90° Repositions

Advanced Propulsion
Atlas IIAS

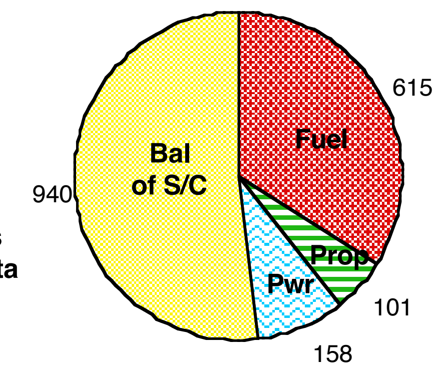


450% More Repositions
35% Faster Repositions
5 Year Life Extension

4J MBG/Li-Poly
Chem + Hall Insertion
5 kW Hall SK, Repos

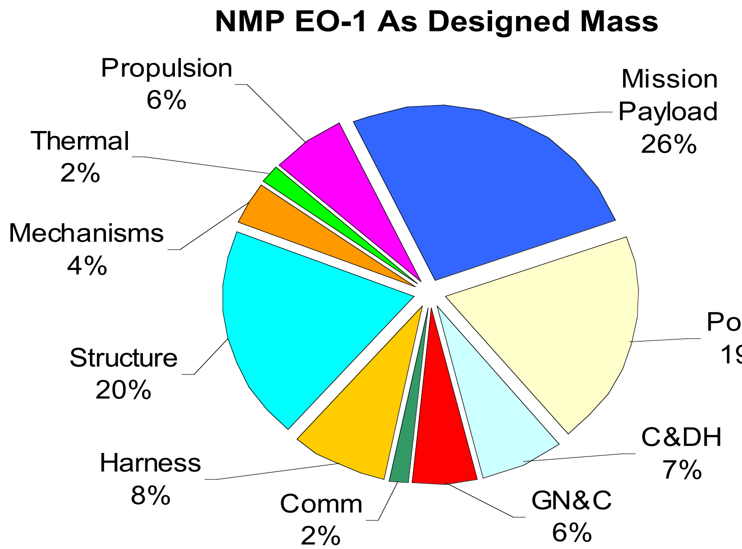
1815 kg Launch Mass
6.2 kW Array (BOL)
15 Year Spacecraft Life
10x9 Day 90° Repositions
LV Class Reduction to Delta
or 2 Sats per Atlas

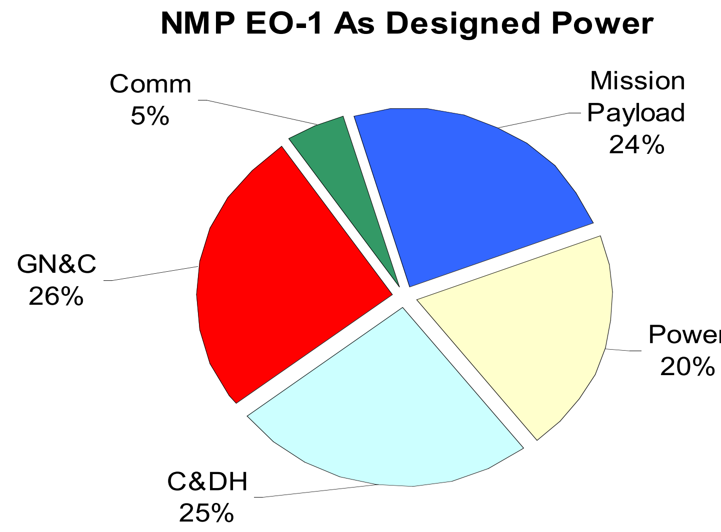
Adv Power & Propulsion
Delta II 7925

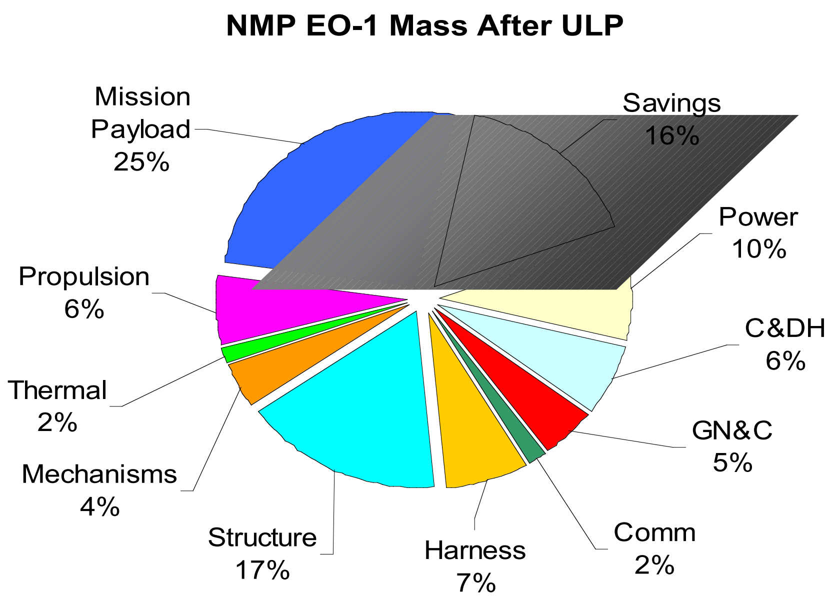


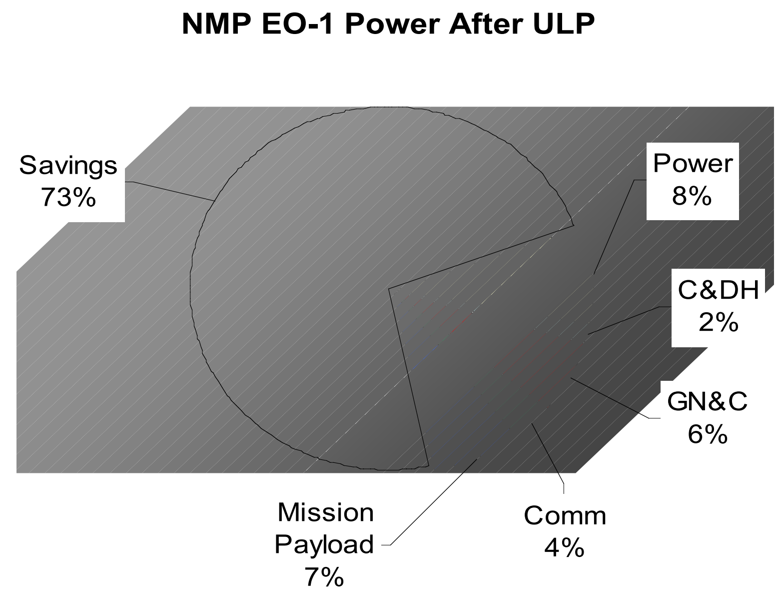
$200M Launch Savings
35% Reduced Trip Time
5 Year Life Extension

Potential Impact of RTULP Electronics - Example









Potential to shrink electronics box volume (instrument and spacecraft) by 10X

ECT Issues – Developing a Process to Improve NASA's Long Term Technology Development

- **FY 02 - A transient period:**
  - $37.5M in remaining CETDP tasks to be completed in 02
  - 2 years remaining on $40M/year CETDP NRA
  - Unbalances in critical/unique-to-NASA technology competencies
  - Current portfolio poorly connected for transition to user
- **FY 02 – Critical needs:**
  - Systems analyses of high priority future systems based on current SOA technologies to establish baseline capabilities
  - Development approach that provides transition incentives to both developers and users
- **FY 03 – Updated technology foci:**
  - Systems driven (metrics approach is a challenge)
  - Mission connected
  - Bases for FY 03 NRA solicitation (FY 04 awards)

Computing Information and Communications Technology (CICT) Program - $154.9M

Intelligent Systems Project ($79.6M) - Smarter, more adaptive systems and tools that work collaboratively with humans

Computing and Communication Systems Project ($36.9M)) - Seamless access to ground-, air- and space-based distributed computing, information, and knowledge

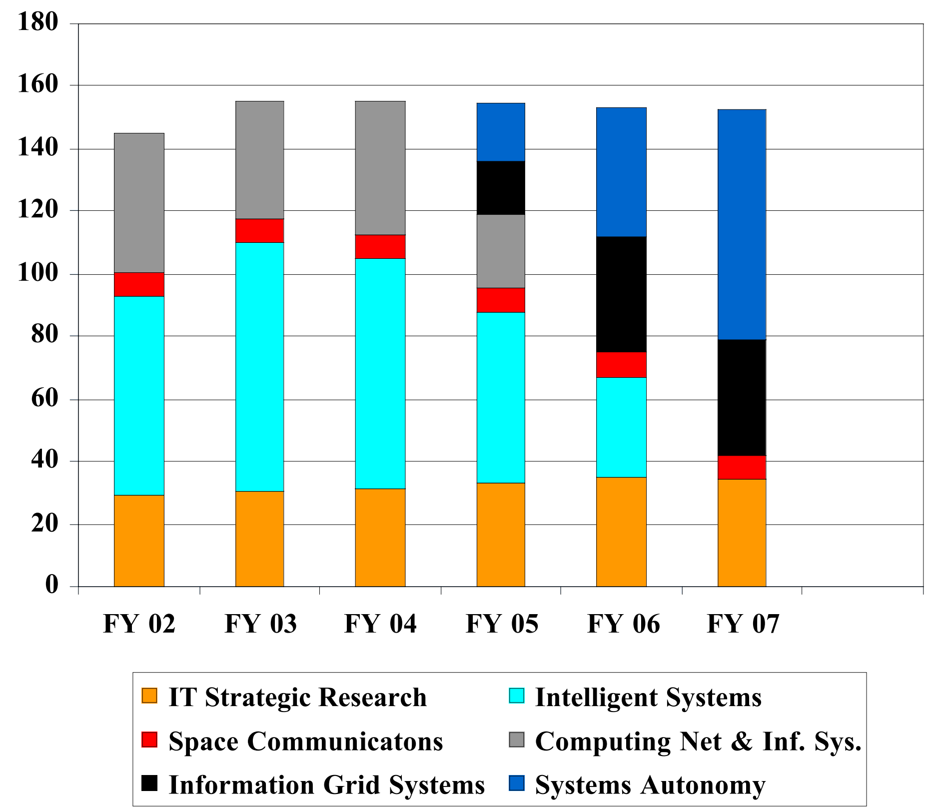
Space Communications Project ($7.6M) - Revolutionary space communications technologies

IT Strategic Research Project $(30.7M) - Broad portfolio of fundamental information and bio/nano technologies for infusion into NASA missions

Information Grid Systems Project (future)

Systems Autonomy Project (future)

CICT Funding, $M



Earth Science Spacecraft Electronics

5 years ago

- 15 Mip, R3000 based processors on EO-1 and MAP use commercial development systems and commercial real-time operating systems (combining spacecraft functionality in single processor... i.e. C&DH and GNCC)
- Solid State Recorders single card holds many 5 to 10 gigabits... Landsat-7 140 gigabit SSR is about 4 cu ft
- Chip-On-Board technology to increase density / decrease cost
- Dedicated TAXI or RS-422 interfaces adequate for science data (1-10 mbps)

Today

- Increasing downlink capability with X-Band direct downlinks at 105+ megabits per second to a ground station (TDRSS costs have become very high)
- Science data moving at 800 megabits per second from the instrument into the data system for EO-1
- 20 gigabits of RAM on a single card

5 to 10 years hence

-Optical downlinks of 2 gigabits per second up and down... higher data throughput and ability to upload new algorithms

-- On board storage requirements unchanged

- On board science computing requires 10's to 100's of gigaflops for science data processing and direct generation and downlink of products

- On board spacecraft processing requirements jumps to 100's of mips for autonomous ops and formation flying

Autonomous Sciencecraft Constellation

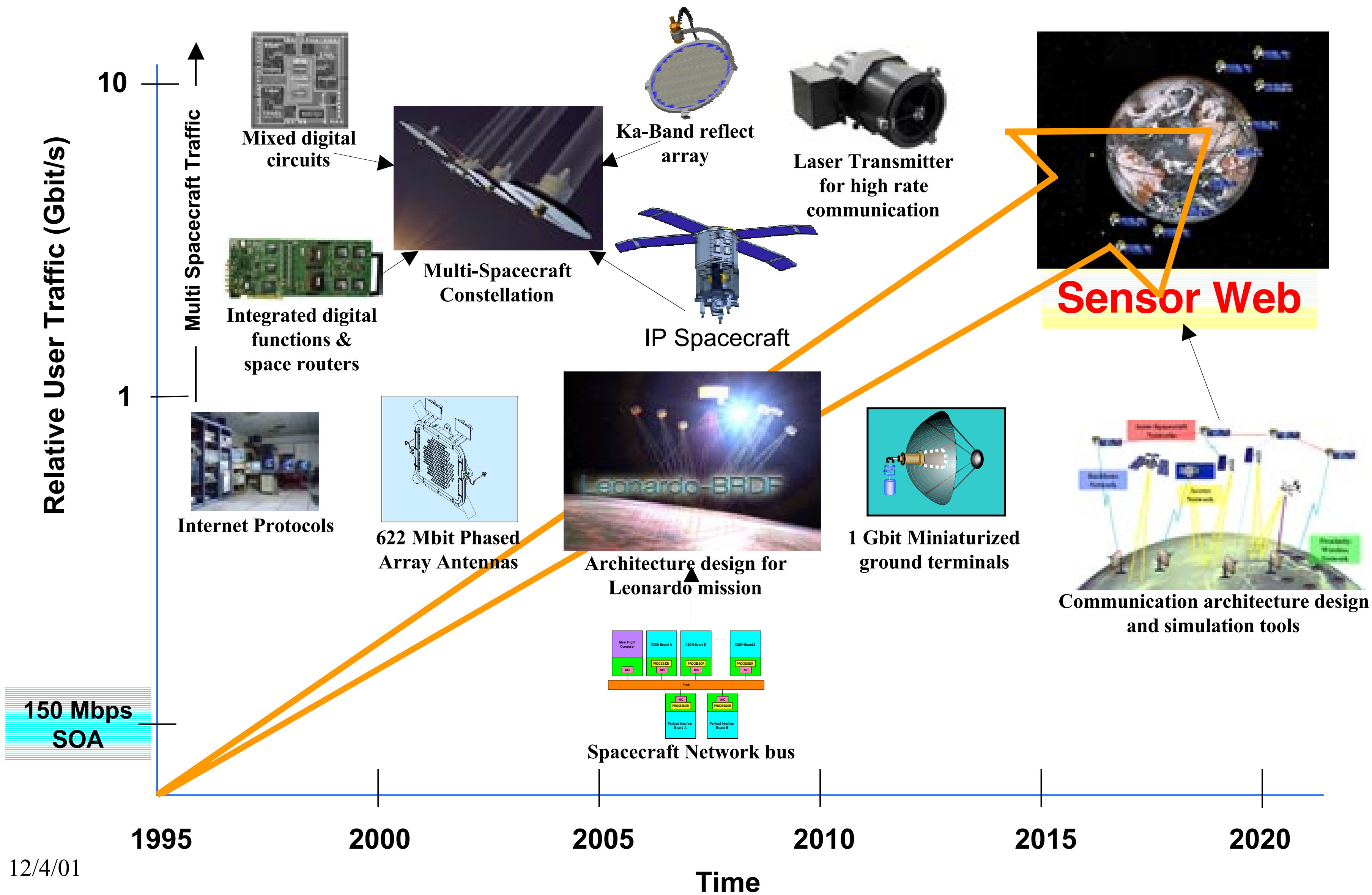
Tasks

- Detect surface-change events on 1st pass and autonomously reconfigure constellation for higher resolution observation on repeat pass.
- Onboard science summarization & prioritization to maximize science return for fixed bandwidth.

Demonstrate intelligent downlink selection and autonomous retargeting on AF TechSat-21 mission

- Winning New Millennium Program ST6 phase A proposal validates intelligent systems technologies from the Space Base
  - **Onboard data processing**
  - **Fast onboard planning & execution**
- Enables observation of short-lived surface-change science opportunities
  - **Earth:** lava flow, floods, iceberg calving
  - **Mars:** dune motion, ice cap adv./retreat
  - **Io:** observe volcano eruptions
  - **Europa:** surface change from tidal stress

High Rate Communication Network Technologies for Earth Science Enterprise



DAS Optimization Effort - Futures

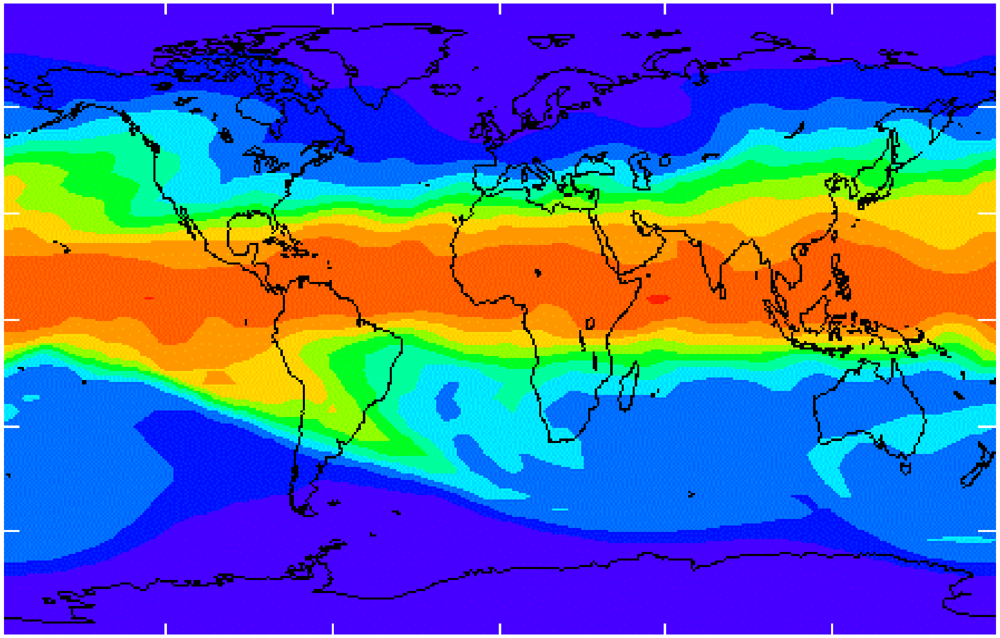
Now that we have achieved 200 d/d, DAO would like to push the Ames technology to the limit. The capability is sought is as follows:

Desires

- ***Simulate years of climate evolution***
- ***Re-analyze decades of data***
- ***Execute at 10x the resolution***
- ***Execute with 10x the observations***

Needs

- ***Another 10-100x in performance***
- ***Larger compute systems***



Engineering for Complex Systems (ECS) Program - $28M in FY03

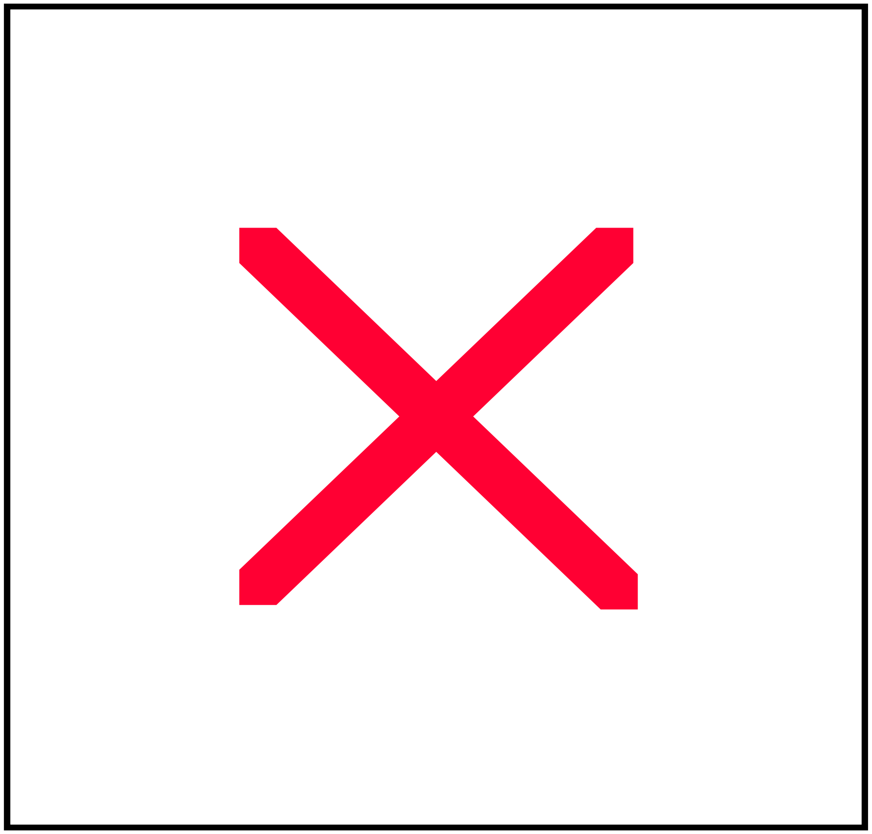
(Formerly "Design for Safety")

System Reasoning & Risk Management Project ($9M) - Better tools for life-cycle risk analysis, design robustness, failure modeling, and system trade-offs, addressing system complexity, design, and risk propagation profiles. Model Based Reasoning for growing analysis size and complexity.

Resilient Systems & Operations Project ($14M) – Replace rigid, non-adaptive systems by developing intelligent software technologies that provide robust and resilient operations as well as advanced diagnostic tools for evaluating and testing intelligent software systems.

Knowledge Engineering for Safe Systems Project ($5M) - Human and organizational risk factors, methods to capture and discover the effects of the human and organizational interactions, organizational and human knowledge capture for complex systems

Simulation Based Life Cycle Mgt (future) -



Enterprise Interactions

- Ratings of FY 01 tasks by Codes M, S, and Y used for FY 02 planning by ECT and CICT programs, March
- ARC CICT key personnel personnel participating on Code S IT Assessment Study Team, March-October
- Enterprise Technology leaders invited to Code R FY 03 Planning Meeting, July
- Draft program plans distributed to enterprises, October
- Discussions of issues with technologists Codes S and Y in telecons and meetings
- Video-cons with Enterprises to define mission-life-cycle relevance studies, review deliverables and plans targeted to begin in late-November to support program plan revisions due in late January